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CHEMISTRY DIVISION - PROTECTIVE CHEMISTRY SECTION

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CHAMBER TESTS WITH HUMAN SUBJECTS
XIV. TESTS OF NEW CARBON CLOTHING

By

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- Report No. P-2701 -

~~CONFIDENTIAL~~

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NRL Problem P-60
as

ABSTRACT

This report describes the results of chamber tests of new carbon clothing. Three types of carbon clothing were studied: coated, impregnated and carbon-rayon.

One modification each of the coated and impregnated types gave protection comparable to that given by CC-2 impregnated clothing in similar tests. Several modifications of the carbon-rayon type gave protection superior to that given by CC-2 impregnated clothing in similar tests.

The protection given by carbon clothing against HN-1 vapor was of the same order as that given against H vapor. CC-2 clothing gives very poor protection against HN-1 vapor.

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INTRODUCTION

A. Authorization

1. This work was authorized under Project 547/41, "Maintenance, Bureau of Ships", dated 16 December 1940. The problems which were proposed for study were given in Bureau of Ships letter S-S77-2(Dz), Serial 811, of 17 December 1940.

B. Statement of Problem

2. This investigation was undertaken as a continuation of the evaluation of the protection against vesicant vapors afforded by new clothing containing activated carbon.

C. Known Facts Bearing on the Problem and Theoretical Considerations

3. Carbon cloth may be divided into three types, depending on the method used for incorporating the carbon in the fabric. These are the coated, impregnated and synthetic fiber types. The coated type is relatively easy to manufacture but can only be made in piece goods. Some difficulty has been experienced in sewing this type of cloth because of the hard abrasive layer of carbon. The cloth also tends to "crock", thereby losing its protective value through loss of carbon. The impregnated type is also relatively easy to manufacture, since cloth or garments can be impregnated by methods similar to those used at present for CC-2 impregnations. The synthetic fiber type, in which the carbon is incorporated directly in the fiber, is the most difficult to manufacture and therefore is the most expensive. Also, volume production of this type is more limited due to the more specialized equipment required. However, in some respects it is preferable to the other types since the material does not "crock", a high percentage of carbon can be incorporated in the cloth and still give a cloth with a good "hand" and appearance, greater uniformity of carbon content can be obtained and the carbon is not readily removed by laundering. Early difficulties in the preparation of carbon cloths due to poisoning of the carbon during manufacture of the cloth or fiber, as well as many other technical difficulties, have been largely overcome through the studies of NDRC investigators.

4. Two modifications of the coated type were studied in this investigation, the August 1943 Model and S-38. Four modifications of the impregnated type were studied, R & H (Rhoplex), casein, improved casein and methocel. NRL Report No. P-2322, "Evaluation of Activated Carbon As An Anti-Vesicant Agent in Protective Clothing", describes the composition of some of these cloths. Seven modifications of the synthetic fiber type were studied. Most of these are described in NRL Report No. P-2655, "Evaluation of Carbon-Rayon Protective Fabrics".

D. Previous Work Done at This Laboratory

5. This report is the fourteenth of a series on "Chamber Tests with Human Subjects" in which the results obtained in the evaluation of various protective equipment against the vesicant effects of persistent chemical

warfare agents are reported. The fourth, fifth and thirteenth reports of the series, NRL Reports Nos. P-2239, P-2464, and P-2604 describe earlier work on carbon clothing. NRL Report No. P-2510, "Methods for the Determination of the Vesicant Agent Content of Contaminated Carbon Clothing", gives the procedures employed for analysis of the vesicant agent content of the clothing described in this report. NRL Report No. P-2570, "The Persistence of H and HN on Carbon Clothing", gives data on the persistence of agents on carbon cloth under various conditions of storage. NRL Reports Nos. P-2322 and P-2655, mentioned above, present additional studies on carbon clothing including summarized chamber data.

EXPERIMENTAL

A. Procedure

6. The chamber used in these tests and its operation are described in NRL Report No. P-2208. The method used for testing carbon clothing was similar to that used for CC-2 impregnated clothing, described in earlier reports of this series, with the difference that the carbon clothing was worn continuously during the tests whereas the CC-2 impregnated clothing was not.

7. The chamber tests were conducted as follows: The subjects, always dressed in the same suits and accessories, were given successive daily exposures to the vesicant vapor in the chamber at 90°F, 65% R.H. and 2-2.5 m.p.h. wind velocity. In tests with H, exposures were generally at a CT of 1200 (20 γ H/l. for 60 min.) and in a few tests, at a CT of 2400 (40 γ H/l. for 60 min.). In the test with HN-1 the exposures were at a CT of 2000 (33.3 γHN-1/l. for 60 min.). The carbon clothing was worn continuously during a test except for readings. The men were examined and read by the Medical Officer before each exposure, and each subject was withdrawn from the test when he had incurred a reading of E (intense erythema) or greater on any part of the body. The successive daily exposures were continued until all the men had "broken" or were withdrawn by the Medical Officer for other reasons. The average number of exposures tolerated was used as the criterion of protection afforded during a particular test.

8. Each man exposed to H vapor in the chamber was equipped with the following:

(a) Navy diaphragm mask, Mark IV (with CC-2 impregnated sleeves on the hose connecting tubes).
(b) Carbon cloth suits.
(c) Two pairs of CC-2 impregnated socks.
(d) One pair of CC-2 impregnated wool elbow length gloves.
(e) CC-2 impregnated shorts for 1-1/2 layer tests, plain shorts for 1 layer tests.
(f) Plain undershirts (skivvies).
(g) Overshoes (Arctics).

In some of the early tests, S-330 Protective Ointment was applied to the face and neck. This was discontinued when it was found (see NRL Report No. P-2604) that the use of ointment decreased the protection given by carbon clothing. In several cases a special CC-2 impregnated or carbon cloth collar was worn around the neck after a man sustained an intense erythema of the neck so that he could continue the test without further damage to this area. This was done since a neck burn was not considered a legitimate suit "break" when ointment was used in the test.

9. In the tests with HN-1, the CC-2 impregnated shorts, gloves and socks were replaced with carbon cloth shorts, mittens and socks, respectively.

10. In the test of carbon-rayon #166, sufficient cloth was not available to make the number of suits necessary for a standard test. The purpose of this test was primarily to obtain a comparison with carbon-rayon #176. Therefore, since most of the "breaks" with carbon clothing occur on the shoulders and upper back, a section about one foot square was cut out of carbon rayon #176 suits in the area of one shoulder and the upper back and replaced by a carbon-rayon #166 patch. The other shoulder thus served as a control.

11. In order to test the effect of desorption of vesicant from the cloth at the time of a "break" in two of the tests the suits were put on and worn continuously by new unexposed men immediately after the suits "broke". These men wore the clothes under normal room conditions and were not given additional exposures. These desorption tests were continued until the new men "broke" or until it was considered that desorption was not pronounced.

12. Samples were taken from the suits from time to time during the course of most of the tests and analyzed for vesicant agent "pick-up" by methods described in NRL Report No. P-2510. The samples were usually cut with a 1 $cm.^2$ die from the pockets of the jumpers.

B. Results and Discussion of Results

13. All but one of the tests of carbon clothing in the large chamber were with H vapor. The data for these tests are presented below according to the type of clothing used. The one test with HN-1 was carried out using carbon-rayon #110 and is described after the tests with H.

(1.) Carbon-Coated Cloth

14. Tests of two modifications of carbon-coated cloth were carried out. The tests of Aug. Model clothing were reported in NRL Report No. P-2239. The test using S-38 clothing was carried out as a standard "man-break" test, and samples from the pockets of each suit were removed for analysis by both the DB-3 and NaOCl methods. The data obtained in these tests are presented in Tables I and II. More complete data on the S-38 test are presented in Tables XII and XXVII in the Appendix.

Table I

Carbon-Coated Cloth - Physiological Data

Conditions: H at CT 1200 (60 min.); 90°F, 65% R.H.

Cloth Modification	Type of Test	No. of Men	No. of "Breaks"	Av. No. of Exp. Tolerated	Av. Total CT Tolerated
Aug. Model	1 layer	4	2	3.0+	3600+
S-38	1-1/2 "	7	7	6.0	7200

Table II

Carbon-Coated Cloth - Analytical Data

Total "Pick-up" in γ H/cm.^{2} - NaOCl Method.

Cloth Modification	Exposure Number					
	1	2	3	4	5	6
Aug. Model	26	38	32	50	58	-
S-38	(4)*	17	(4)*	37	44	46

* DB-3 Method.

15. The data in Table I show that the S-38 clothing was superior to the Aug. Model in the protection it afforded. The value of 6.0 exposures is comparable to the average value of 6.1+ exposures tolerated for CC-2 impregnated clothing. (See NRL Report No. P-2602). The S-38 suits have the disadvantage of being quite stiff and do not soften readily on wear.

16. Assuming a linear relationship between H "pick-up" and number of exposures, a plot of the data in Table II indicates that the Aug. Model suits picked up 12-15 γ H/cm.^{2}/exp., and the S-38 suits picked up 8.5 γ H/cm.^{2}/exp. No explanation is available for the low values obtained by the DB-3 method.

(2) Carbon Impregnated Cloth.

17. Three tests of two binder modifications of carbon impregnated cloth were carried out. They were the casein, improved casein and methocel systems. All tests were carried out as standard 1-1/2 layer "man-break" tests at CT 1200. Samples from the pockets of all the suits in the casein and methocel tests were analyzed for H "pick-up" by the NaOCl method. The results of these tests are summarized in Tables III and IV. More complete data are given in Tables XIII through XV and XXVII in the Appendix.

Table III

Carbon Impregnated Cloth - Physiological Data

Conditions: H at CT 1200 (60 min.); 90°F, 65% R.H.

Cloth Modification	Type of Test	No. of Men	No. of Breaks	Av. No. of Exp. Tolerated	Av. Total CT Tolerated
Casein	1-1/2 layer	7	6	7.1+	8520+
Improved Casein	1-1/2 "	8	8	2.0	2400
Methocel	1-1/2 "	7	6	3.7+	4440

Table IV

Carbon Impregnated Cloth - Analytical Data

Average Total "Pick-up" in γ H/cm.^{2} - NaOCl Method.

Cloth Modification	Exposure Number 1	2	3	4	5	6	7
Casein	28	-	49	-	83	-	86
Methocel	5	22	40	49	-	-	-

18. The data in Table III show that the casein-carbon impregnated cloth gave protection which compares very favorably with the combined average of 6.1+ exposures for CC-2 impregnated cloth (25% binder). However, the cloth was very stiff and did not soften readily on wearing. In an attempt to overcome this difficulty, the improved casein formulation was used giving suits with a much better "hand", but, as can be seen from Table III, giving much lower protection. Although analytical data is not available, visual inspection showed that the improved casein suits had a much lower carbon content than the older casein suits. Undoubtedly this is the reason the protection was so much poorer. The methocel suits gave less protection than that given by CC-2 impregnated suits for this type of test.

19. Assuming a linear relationship between H "pick-up" and number of exposures, a plot of the data in Table IV indicates that the casein suits "picked-up" 16 γ H/cm.^{2}/exp. and the methocel suits 12 γ H/cm.^{2}/ exp.

(3) Carbon-Rayon Cloth

20. A number of modifications of carbon-rayon cloth have been tested. Most of the tests were conducted as 1-1/2 layer "man-break" tests. In view of the difficulty of keeping men in a long test of this nature, some of the tests were carried out at a CT of 2400 (60 min.) per exposure instead of the usual 1200. Thetest with carbon-rayon #166 was a shoulder patch test as described in the Procedure. One of the pockets in the carbon-rayon

#176 suits used in this test was replaced by carbon-rayon #166 cloth so that samples for analysis might be removed from them during the course of the test. Samples from the other pocket (#176) were also removed for analysis. In the tests of Costa rayon and the first test of carbon-rayon #110, samples for analysis were taken from 6 different areas of the suits after the suits were removed from the test. In all other cases samples were taken from the pockets of all or nearly all the suits in a test. Both the NaOCl and DB-3 methods were used. The physiological results are summarized in Tables V and VI. More complete data are given in Tables XVI through XXV and XXVII in the Appendix. The analytical results are summarized in Tables VII and VIII.

Table V

Carbon-Rayon Cloth - Physiological Data

Conditions: CT 1200 or 2400 (60 min.); 90°F, 65% R.H.

Cloth Modification	Type of Test	CT of Exp.	No. of Men	No. of "Breaks"	Av. No. of Exp. Tolerated	Av. Total CT Tol.
Costa	1 layer	1200	4	4	6.0	7200
Costa	1-1/2 "	1200	4	3	6.5+	7800+
110	1-1/2 "	1200	6	6	5.3	6360
148	1-1/2 "	1200	4	2	10.5+	12600+
176	1-1/2 "	2400	8	7	4.5+	10800
191	1-1/2 "	2400	7	7	4.4	10560
193	1-1/2 "	2400	8	7	4.9+	11760+
166	Shoulder Patch	2400	4	3	2.0+	4800+

21. The data in Table V show that carbon-rayon #148, 176, 191 and 193 are comparable in the protection they afforded and are superior to the other modifications. The Costa and carbon-rayon #110 contain N-44 carbon whereas the carbon-rayon #148 and #176 contain N-182 carbon and the carbon-rayon #191 contains PCI carbon. It appears, therefore, that N-44 carbon is inferior to the other two in the protection it affords in carbon-rayon cloth. The N-182 and the PCI carbons appear to be comparable since the carbon content and weave of the carbon-rayon #176 and 191 are essentially the same.

22. The effect of the amount of carbon in the carbon-rayon fiber on the protection given can be seen from the results of three of the tests with carbon-rayon cloths which differ only in the percent of carbon present in the fiber. The data are summarized in Table VI.

Table VI

Effect of Percent Carbon in Carbon-Rayon Fiber

Carbon-Rayon Type	% Carbon in Rayon Fiber	No. of Exp. Tolerated*	Total CT Tolerated
176	32	4.5+	10800+
193	28	4.9+	11760+
166	22	2.0+	4800+

*See Table V.

From the results given in Table VI it appears that a carbon content of 28% or more gives essentially the same protection but that somewhere between 28% and 22% the protection begins to drop off. For mechanical reasons it would be desirable to have the smallest amount of carbon in the fiber and still retain maximum protection.

23. Table VII is a summary of the analytical data obtained in the carbon-rayon tests. Table VIII presents the H "pick-up" rate of the various cloths as measured by the NaOCl method only. These values were obtained from plots of the data presented in Table VII assuming a linear relationship between "pick-up" and number of exposures.

Table VII

Carbon-Rayon Cloth - Analytical Data

Average Total "Pick-up" in $\gamma H/cm.^2$ - NaOCl Method Unless Marked.

Cloth Modification	CT of Exp.	Exposure Number 1	2	3	4	5	6	7	8	9	10	11	12
Costa	1200	-	30	71	-	-	94						
110	1200	8	22	24	38	42	39						
148	1200	21	26	34	73	73	76	83	99	109	112	114	155
148*	1200	13	24	33	61	57	70	69	88	100	71	89	75
176	2400	-	64	-	147								
191	2400	-	71	-	132								
193	2400	-	61	-	142								
166	2400	29	55										
176**	2400	27	57										

* DB-3 Method on samples taken at the same time and from the same suits as those used for the NaOCl Method.
** Same test as carbon-rayon #166. Samples removed from other pocket.

Table VIII

Carbon-Rayon Cloths - H "Pick-up" Rate

Cloth Modification	CT of Exp.	γ H/cm.^{2}/exp.	γ H/cm.^{2}/1200 CT
Costa	1200	17	17
110	1200	9	9
148	1200	13 (11*)	13 (11*)
176	2400	35 (30**)	18 (15**)
191	2400	35	18
193	2400	35	18
166	2400	30	15

* DB-3 Method.
** From carbon-rayon #166 test.

24. From the data in previous tables it can be seen that, with the exception of carbon-rayon #110 and S-38 carbon-coated cloths, the "pick-up" per unit CT is fairly constant. Therefore, it is obvious that no definite relationship exists between "pick-up" and protection given. The slightly lower values obtained by the DB-3 method for the carbon-rayon #148 are probably due to gradual hydrolysis of the agent on the cloth during the test. It is rather surprising that the "pick-up" of the carbon-rayon #176 and #166 are the same considering the difference in carbon content of the two cloths.

(4) Desorption Tests

25. Two suits from the 1-layer Costa-rayon test were put on by new men immediately after they were "broken". After 3 days of wear one man had vesication of the neck and scrotum; the other man had no significant burns after 5 days of wear. (See Table XVII in the Appendix). The 8 suits from the carbon-rayon #148 test were all tested for desorption by the same method. After 3 days of wear the men averaged a moderate erythema for the maximum reading (see Table XXI in the Appendix). It is obvious that a significant degree of desorption occurred from the suits which had been "broken" under the test conditions used. Chemical tests (unpublished data) have shown that the leakage of H vapor through a good type of carbon cloth is negligible, so that the burns sustained in a regular "man-break" test result largely from desorption rather than leakage. This desorption represents one of the disadvantages of carbon cloth over chemically impregnated protective cloth.

(5) Test with HN-1

26. One of the advantages of carbon cloth over CC-2 impregnated cloth is the much greater protection it may afford against vesicants in general. NRL Report No. P-2464 gives data obtained in the arm chamber demonstrating this advantage. In order to obtain data in the large chamber a 1-1/2 layer test was run using HN-1 at a CT of 2000 (60 min.) and carbon-rayon #110 suits. At the end of the test samples from all the suits were analysed for HN-1 "pick-up" by the $AgNO_3$ method. The results are summarized in Table IX. More complete data are given in Tables XXVI and XXVII in the Appendix.

Table IX

Carbon-Rayon #110 - Test with HN-1

No. of Men	No. of "Breaks"	Av. No. of Exp. Tolerated	Av. Total CT Tolerated	γHN-1/cm.^{2}/exp.
6	5	5.0+	10,000+	77

27. From Tables V and IX it can be seen that carbon-rayon #110 gave protection against HN-1 at a total CT of 10,000+ and against H at a total CT of 6360. CC-2 impregnated suits (25% binder) protect against 7320+ CT of H under comparable conditions of testing, whereas, in a test with HN-1 under summer conditions, CC-2 suits did not give adequate protection at CT 400.

28. The abnormally high "pick-up" of HN-1 in this test is to be noted. It was found in arm chamber tests (see NRL Report No. P-2464) that the "pick-up" of HN-1 or HN-3 was higher than the "pick-up" of H. No satisfactory explanation has been found for this phenomenon.

C. General Discussion

29. Many factors must be considered in a comparison of carbon clothing and CC-2 impregnated clothing. Direct comparisons are not always possible since the mechanism of protection is different. A few of the advantages and disadvantages of each are presented below.

30. The much greater protection afforded against HN-1 by carbon-rayon cloth than by CC-2 cloth has been demonstrated. This property of carbon cloth, its ability to protect against vesicant agents other than H, is one of its most promising features. Even against H, the protection afforded by carbon-rayon #148 in a standard 1-1/2 layer "man-break" test at CT 1200 was 10.5+ exposures, whereas for CC-2 clothing the average was 6.1+ exposures.

31. A strict comparison of the protection on a total CT of exposure basis cannot be made between carbon cloth and CC-2 impregnated cloth since it has been shown (see NRL Report No. P-2528) that the protection afforded by new CC-2 impregnated clothing is more a function of the time of exposure than the CT of exposure. A comparison of the results obtained with carbon-rayon #148 and #176 (which are essentially the same) indicate that the total CT of exposure is more important than the time of exposure in the protection afforded by carbon cloth.

32. It was pointed out in NRL Report No. P-2603 that, due to the unusual leakage characteristics of CC-2 cloth, the individual "breaks" in any given "man-break" test occur over a wide number of exposures. As can be seen in Table XXVII in the Appendix, this is not true for carbon clothing, since the "breaks" in any given test are grouped closely. Furthermore, while the "breaks" with CC-2 clothing are usually gradual, the "breaks" with carbon clothing are more abrupt. It appears, therefore, that since new carbon cloth does not show leakage as measured chemically, a fairly definite loading of agent must be obtained on any given type of carbon cloth before desorption becomes important. The desorption of agent is one of the disadvantages of carbon cloth, since a contaminated garment remains a potential hazard for some time.

33. A further disadvantage of carbon clothing is that the carbon may be poisoned by a number of substances, thus decreasing its protective value. For example, as shown in NRL Report No. P-2604, oil, S-330 Protective Ointment and water all have a deleterious effect on carbon clothing. In the test with carbon-rayon #148 described in the present report five of the original eight men had to be removed from the test due to neck burns because ointment was used in the test (see Table XX in the Appendix).

34. A comparison of carbon and CC-2 clothing in regard to such factors as ease of regeneration, reimpregnation, laundering, wearing life, etc., will be presented in other reports on carbon clothing now in process of preparation.

SUMMARY AND CONCLUSIONS

1. Chamber tests with H and HN-1 have been conducted to evaluate the protection afforded by new carbon clothing. Three types of carbon clothing were studied, coated, impregnated and carbon-rayon. Samples from the clothing were analyzed during the tests to determine agent "pick-up".

2. Model S-38 carbon-coated cloth gave protection comparable to CC-2 impregnated cloth, i.e., 6.0 vs. 6.1+ exposures, respectively.

3. Three modifications of carbon impregnated cloth were tested against H. Of these, the casein system gave protection for 7.1+ standard exposures, the Methocel system for 3.7+ and the improved casein system for 2.0. The improved casein cloth was softer than the original casein cloth but contained insufficient carbon to give comparable protection.

4. Seven modifications of carbon-rayon cloth were tested against H in the chamber. Of these, carbon-rayon #148, 176, 191 and 193 gave comparable protection (10500-12600 CT). This was considerably better than that given by the other types of carbon cloth or CC-2 impregnated cloth. From the test with carbon-rayon cloth the following conclusions were drawn:

(a) The total CT of exposure was more important in the protection afforded by new carbon cloth than the time of exposure.

(b) Carbon-rayon cloth containing N-182 carbon gave greater protection than cloth containing N-44 carbon. Cloth containing PCI carbon gave protection comparable to that containing N-182 carbon.

(c) In carbon-rayon cloths which differ only in the percent of carbon in the fiber, those with 28% and 32% carbon gave the same degree of protection while one containing 22% carbon gave considerably less protection. A carbon content of 28% or less therefore, would be the most desirable, since greater wearing life can be obtained with a lower carbon content.

5. The individual "breaks" in given tests with carbon clothing were abrupt and grouped closely together. This was in contrast to the "breaks" observed with CC-2 impregnated clothing which were gradual and in any one test range over a considerable number of exposures.

6. Two modifications of carbon-rayon cloth were tested for desorption by wear only immediately after they were "broken" in the standard "man-break" tests. Significant burns resulted in both tests, showing that vapor contaminated carbon cloth garments presented a potential hazard even when no further exposures were given.

7. Results of analyses for agent "pick-up" of samples taken from suits during and after chamber tests showed no correlation with the protection given. The H "pick-up" for all the carbon cloths except carbon-coated S-38 and carbon-rayon #110 ranged from 12 - 18 γ H/cm.^{2}/1200 CT.

8. A large chamber "man-break" test on carbon-rayon #110 was carried out using HN-1 at CT 2000 (60 min.). An average of 5.0+ exposures was tolerated. Against H, carbon-rayon #110 gave protection for 5.3 exposures at CT 1200 each.

9. The loss in protection given by carbon clothing as the result of wear and other factors will be presented in later reports.

RECOMMENDATIONS

1. It is recommended that the better types of new carbon-rayon cloths (#148, 176, 191, 193) be considered as superior to standard new CC-2 impregnated cloth (25% binder) in the protection afforded against H vapor.

2. It is recommended that new carbon-rayon cloths be considered as giving good protection against HN-1 vapor and therefore as being much superior to CC-2 impregnated cloth in this respect.

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The subjects participating in these tests were volunteer personnel from NTC, Bainbridge, Maryland.

APPENDIX

Table X

Legend - Physiological Readings

Symbol	Reaction
0	No Reaction
E-?	Trace
E-	Mild Erythema
E°	Moderate Erythema
E	Intense Erythema
E+	Papular Erythema
NPV	Numerous Pin-point Vesicles
V	Vesicle
NV	Numerous Vesicles

Table XI

Legend - Body Areas

Abbr.	Area	Abbr.	Area
aaf	anterior axillary folds	lne	lateral neck
aar	anterior arms	lth	lateral thorax
abd	abdomen	lum	lumbar region
af	axillary folds	ne	neck
ale	anterior legs	oint	area covered by ointment
ane	anterior neck	paf	posterior axillary folds
ar	arms	par	posterior arms
ash	anterior shoulders	pen	penis
athi	anterior thighs	ple	posterior legs
ax	axillae	pne	posterior neck
bt	buttocks	pop	popliteal fossae
C_7	7th cervicular region	psh	posterior shoulders
cf	cubital fossae	pthi	posterior thighs
cl	clavicles	sc	scapulae
dh	dorsum of hands	scr	scrotum
dth	dorsal thorax	sh	shoulders
el	elbows	st	upper sternum
fa	forearms	th	thorax
igf	intergluteal folds	thi	thighs
il	iliac crest	umar	upper medial arms
ing	inguinal region	vth	ventral thorax
kn	knees	wr	wrists
le	legs		

Table XII

Carbon Coated (S-38)

Conditions: H at CT 1200 (60 min.); 90°F., 65% R.H.
1-1/2 layer (CC-2 impregnated shorts).

Date Started: 7/3/45

No. of Exposures Tolerated	Readings (Hours After Last Exposure) 24	48
7	E ne, ash, cf E° st,psh,sc,dth	E+ ane, lne E sh,aar,cf,pne,sc,dth E° st,fa,dh,wr,ax,kn
6	E aar,psh E° ne,st,ash,cf,af,ax, th,kn,el,sc,pop	E ane,lne,sh,sc,cf,af,dth E° ax,lth,vth,athi,kn,ale,pop
5	E ne,cf,paf,psh,C_7,sc, pop E° st,cl,ash,aar,ax, kn,dth	E ne,sh,aar,cf,ax,sc,pop E° st,cl,af,vth,kn,el,C_7,dth, pthi
6	E ane,psh,sc E° st,cl,cf,kn,pne,lne, el,C_7,dth,pop	E ne,st,cf,psh,sc,dth E° ash,dh,wr,lth,athi,kn,ale, C_7,pop
5	E dth E° ne,st,cf,pop	E dth E°ne,st,cf,ax,kn,el,pop
7	V ane E sh,cf,paf,sc,dth E° lne,umar,lth,vth, athi,kn,ale	E ane,lne,st,sh,umar,cf,lth, kn,paf,sc,dth E° fa,dh,wr,athi,ale,pne,el,pop
6	E cf E° kn	E cf,psh,sc,dth,pop E° ne,st,athi,kn,ale

Av. 6.0

Table XIII

Carbon Impregnated (Casein Method)

Conditions: H at CT 1200 (60 min.); 90°F., 65% R.H.
1-1/2 layer (CC-2 impregnated shorts).

Date Started: 3/20/45

No. of Exposures Tolerated	Readings (Hours After Last Exposure)	
	24	48
8	E sh,sc,dth E° ane,st,cf,ax,lth,kn, pop	E sh,umar,aar,cf,ax,lth,kn, paf,cl,sc,dth,lum,pop E° ane,st,athi,lc
8	E ane,ax,paf,psh,C_7,sc, dth	E ane,ax,paf,psh,C_7,sc,dth E° lnc,cf,kn,lc,pthi,pop
7	E ane,ax,paf,psh,sc,dth E° lnc,ash,cf,lth,athi, kn,alc,pnc,cl,C_7,pop	E ane,umar,cf,ax,lth,pnc,paf, psh,C_7,sc,dth E° st,lnc,ash,aar,fa,dh,wr, athi,kn,alc,pop
6	E ax,psh,sc E° anc,lth,par,dth	E ax,paf,psh,sc,dth E° ane,ash,aar,cf,pnc,C_7
7	E psh,sc,dth E° cf,pnc,paf,C_7,lum	E cf,paf,psh,sc,dth E° ane,ash,aar,umar,ax,kn,pnc, cl,C_7,lum,pop
7	E psh,sc,dth E° nc,st,ax,kn	E anc,paf,psh,sc,dth E° lnc,st,cf,ax,athi,kn,alc,pnc
7*	E° psh,sc,dth	E psh,sc,dth E° nc,ax

Av. 7.1+

* In this and all subsequent tables, denotes man withdrawn from test for reasons other than a "break".

Table XIV

Carbon Impregnated (Improved Casein Method)

Conditions: H at CT 1200 (60 min.); 90°F., 65% R.H.
1-1/2 layer (CC-2 impregnated shorts).

Date Started: 9/27/45

No. of Exposures Tolerated	Readings (Hours After Last Exposure) 24	48
2	E cf,thi,kn,le,pop,paf,psh, sc,dth E° ne,st,ash,aar,lth,vth, abd	E sh,cf,ax,th,[illegible]hi,kn,ale,pop E° ne,st (72 hours)
2	E thi,kn,le,pop E° psh,sc,dth	E thi,kn,le,pop E° ash,cf (72 hours)
2	E cf,psh,par E° ne,st,aar,sc,dth	E sh,aar,cf,lth,paf E° ne,st,sc,dth (72 hours)
2	E psh E° ne,st,ash,aar,cf, sc,dth	E psh E° ne,st,sc,dth (72 hours)
1	E pthi,pop,ple E° ne,st,athi,kn,ale	E thi,kn,le,pop,pne E° ane,lne,st
3	E sh,ar,cf,fa,athi,kn, ale,paf,el,sc,dth E° lth,vth,pne,pthi, pop,ple	E+ cf E sh,ar,fa,ax,thi,kn,le,pop, paf,sc E° ne,st
2	E sh,aar,cf,thi,kn,le, pop,sc,dth E° ne,st,lth,vth,abd, par,el	E sh,aar,cf,th,abd,thi,kn,le, pop,paf,sc E° pne,par,el,C_7 (72 hours)
2	E kn,le,pthi,pop E° ne,st	E thi,kn,le,pop E° psh,sc

Av. 2.0

Table XV

Carbon Impregnated (Methocel)

Conditions: H at CT 1200 (60 min.); 90°F, 65% R.H.
1-1/2 layer (CC-2 impregnated shorts).

Date Started: 7/6/45

No. of Exposures Tolerated	Readings (Hours After Last Exposure)	
	24	48
4	E ne,sh,sc,dth E° st,cf,kn,C_7	E+ ane,lne E sh,cf,pne,paf,sc,dth E° st,aar,fa,kn,C_7
3	E psh,sc E° ne,st,kn	E ane,lne,st,wr,psh,sc,dth E° athi,kn,le,phe
4*	E° ane,pne,paf,psh,sc, dth	E sc,dth E° ne,st,sh,cf,C_7
4	E ne,athi,kn,psh,sc E° st,ash,le,dth,pthi, pop	E+ ane,lne E athi,kn,ale,pne,psh,sc E° ash,dh,wr,cl,C_7,pthi,pop,ple
4	E psh,sc E° ne,ash,dth	E ane,lne,psh,sc,dth E° ash,cf,athi,kn,le,pne,C_7
4	E psh,sc,dth E° C_7	E pne,psh,sc,dth E° C_7
3	E ne,st,psh,sc E° ash,aar,cf,kn,cl,C_7	E+ ane,lne E umar,cf,wr,lth,pne,psh,paf, sc,dth E° st,ash,aar,dh,athi,kn,ale, par,cl

Av. 3.7+

Table XVI

Costa Carbon-Rayon Cloth

Conditions: H at CT 1200 (60 min.); 90°F, 65% R.H.
1 layer (plain shorts) - Ointment used on neck.

Date Started: 5/2/44

No. of Exposures Tolerated	Readings (Hours After Last Exposure)	
	24	48
6 (A)	E aaf,vth,ing,scr,thi	E vth,ing,thi E° aaf,lum,scr,bt
6	E scr E° bt,thi,le	E scr E° ne,thi,kn,bt,le
6 (B)	E ne,scr,bt E° cf	E scr,bt E° ne,cf
6	E scr E° bt	E° scr

Av. 6

Note: To determine the effects of desorption, suits (A) and (B) were put on immediately after they were "broken" and were worn continuously by new men. No further exposures were given. (See Table XVII).

Table XVII

Test for Desorption from Exposed Costa Rayon Suits

(See Table XVI)

Conditions: Wear only, no exposure.
1 Layer.

Date Started: 5/8/44

	Readings and Remarks	
Days	Suit A (6 Exp.)	Suit B (6 Exp.)
1	E° lne	No readings E° or greater
2	E ne	No readings E° or greater
3	NPV scr,lne. (Removed from test.)	E° el
4		No readings E° or greater
5		No readings E° or greater (Removed from test.)

Table XVIII

Costa Carbon-Rayon Cloth

Conditions: H at CT 1200 (60 min.); 90°F, 65% R.H.
1-1/2 layer (CC-2 impregnated shorts) - Ointment used on neck.

Date Started: 5/16/44

No. of Exposures Tolerated	Readings (Hours After Last Exposure) 24	48
8*	E ne (oint.?) E° sc, scr	E pne E° ane,lne,scr,sc
8	E dth,sc,pne	E sc,dth E° lth
3	E sc E° scr,dth,ne	E sc E° ne,scr
7	E kn,le,sc E° dth,pop,cf,ne	E ne,sc,kn E° cf,pop

Av. 6.5+

Table XIX

Carbon Rayon #110

Conditions: H at CT 1200 (60 min.); 90°F., 65% R.H.
1-1/2 layer (CC-2 impregnated shorts) - Ointment used on neck.

Date Started: 5/16/44

No. of Exposures Tolerated	Readings (Hours After Last Exposure) 24	48
6	E aaf,ash,ax,kn,sc,dth E° cf,scr,pen	E+ ne E ash,dth,paf
6	E aaf,cf,ash,scr E° sc, dth	E sh,aaf,scr,sc,dth,pop,kn E° ne
6	E+ scr E° ash,aaf,pen,sc,dth, thi,le	E scr E° sh,sc,dth
6	E ax,dth E° ar	E+ sc E dth E° sh,cf,scr,pop,le

Av. 6.0

Date Started: 11/7/44

3	E sh,cl,aar E° dth,pne,el	E ne,st,cl,sh,aar,sc,dth
5	E ash,cf,sc E° psh,lum,pop	E sh,aaf,sc E° ax,pne,lum

Av. 4.0

Total Av. 5.3

Table XX

Carbon Rayon #148

Conditions: H at CT 1200 (60 min.); 90°F, 65% R.H.
1-1/2 layer (CC-2 impregnated shorts) - Ointment used on neck.

Date Started: 10/31/44

No. of Exposures Tolerated	Readings (Hours After Last Exposure) 24	48
6*	E oint. (not included in av.) E° sh	NV oint.
12*	E oint. (Severe conjunctivitis) E° sh,sc,dth	E oint. (conjunctivitis) E° psh,sc,dth
9	E lum E° ne	E lum E° ne
8*	E° Oint., lum (Severe conjunctivitis, not included in av.)	E oint., lum (conjunctivitis)
12*	E oint. (laryngitis, conjunctivitis)	E° oint. (laryngitis, conjunctivitis)
6*	E oint. (not included in av.) E° dh,wr	NV pne E oint.
6*	E oint. (not included in av.)	E oint.
9	E lum E° ne	E lum,ne

Av. 10.5+

Note: Several of the men above were withdrawn due to neck burns. It was demonstrated later that the use of ointment with carbon clothing decreases the protection due to increased desorption of H. Therefore, those men are not included in the average. After the fifth exposure, CC-2 impregnated collars were sewn into the suits to prevent further burns from desorption. In all subsequent exposures, no ointment was used and a CC-2 impregnated hood was worn during exposure in addition to the regular hood.

Table XXI

Test for Desorption from Carbon Rayon #148

(See Table XX)

Conditions: Wear only, no exposures. 3 days continuous wear. 1-1/2 layer (GC-2 impregnated shorts.)

Tests started on day each suit was "broken" in chamber exposures.

No. of Previous Exposures in Chamber	Readings (Hours After 3 Days Wear)		
	0	24	48
6	E° face	E° face	E° face
12	E sc E° face,ne,st, psh	E° face,ne,st psh,sc	E psh,sc E° ne,st,pthi
9	E° face	E° face,ne,st	E° face,ne,psh
8	E° face,ne,st	No further readings available	
12	No readings E° or greater		E° ne,st,cl
6	E pne E° face	E pne E° face,ane, lne,st	E° face,ne,st
6	No readings E° or greater		
9	E° face	E° face,ne, st,psh	E° face

Table XXII

Carbon Rayon #176

Conditions: H at CT 2400 (60 min.); 90°F. 65% R.H.
1-1/2 layers (CC-2 impregnated shorts)

Date Started: 6/26/45

No. of Exposures Tolerated	Readings (Hours after Last Exposure) 24	48
5	E sh,umar,cf,wr,dh,vth, thi,kn,le,pne,paf,par, el,sc,dth,pop E° ane,lne,st	E ne,st,sh,ar,wr,dh,th,thi, kn,le,paf,el,sc,pop
4	E psh,sc,dth E° ne,st,par,el	E+ ane,lne,st E sh,ar,fa,wr,dh,lth,thi,kn, le,pne,el,sc,dth,pop
5	E psh,par,el,sc,dth E° ane,lne,dh,wr	E ane,lne,st,cf,wr,th,paf, psh,par,sc,dth E° ash,thi,kn,le,pop
5	E psh,sc,dth E° wr,kn	E psh,sc,dth E° ne,st,ash,cf,fa,wr,thi, kn,le,pop
5*	E° ne,wr,dh,thi,kn,psh, par,el,sc,pop,ple	E pthi,pop,ple E° ne,st,psh,sc,dth
4	E sc E° psh,dth	E paf,psh,sc,dth E° ne,ash,ar,thi,pop,ple
4	E ane,lne,psh,sc E° par,el,C7,dth	E+ ane,lne E psh,sc,dth E° ash,athi,kr.,ale,pne
4	E psh,sc,dth E° ne,st	E pne,psh,sc,dth E° ane,lne,st,dh,wr,athi,kn

Av. 4.5+

Table XXIII

Carbon Rayon #191 (PCI Carbon)

Conditions: H at CT 2400 (60 min.); 90°F, 65% R.H.
1-1/2 layer (CC-2 impregnated shorts)

Date Started: 6/26/45

No. of Exposures Tolerated	Readings (Hours After Last Exposure	
	24	48
5	E sc E° kn,psh	E ne,st,kn,paf,psh,sc,dth E° ash,aar,cf,dh,wr,athi,ale,pop
5	E sh,thi,kn,pne,par,el, C_7,sc,dth,pop,ple E° ane,lne,st,umar,dh, wr,ale,paf	E ne,st,sh,cf,kn,paf,sc,dth,pthi, pop,ple E° aar,dh,wr,lth,vth,abd,athi, ale,par,el
3	E psh,sc,dth E° ne,st,cf,fa,dh,wr	E pne,psh,sc,dth E° ane,lne,st,cf,dh,wr,pthi,pop
5	E kn,psh,sc,dth,pthi E° ash,ar,cf,athi,le, el,C_7,pop	E sh,ar,cf,wr,lth,thi,kn,le,paf, sc,dth,pop E° ane,lne,dh,el
4	E psh,sc,dth E° ash,aar,cf,pne	E ane,lne,sh,aar,cf,af,lth,sc,dth E° vth,thi,kn,par,el,pop,ple
4	E kn,psh,sc,dth E° ash,thi,pne,C_7,pop, ple	E sh,umar,cf,dh,wr,lth,thi,kn, ale,pne,paf,sc,dth E° ane,lne,st,pop,ple
5	E sh, thi, kn, pne,sc, dth, pop, ple E° ane, lne, aar, cf, dh, wr, lth, ale, paf, par, el	E sh, umar, athi,kn, pne, paf, par, el, sc, dth E° ane, lne, st,aar, cf, dh, wr, le, pthi, pop

Av. 4.4

Table XXIV

Carbon Rayon #193 (28% Carbon)

Conditions: H at CT 2400 (60 min.); 90°F, 65% R.H.
1-1/2 layers (CC-2 impregnated shorts)

Date Started: 6/26/45

No. of Exposures Tolerated	Readings (Hours After Last Exposure) 24	48
5	E sh,wr,kn,pne,paf,sc, dth,pthi,pop,ple E° ane,lne,st,dth,athi, ale	E ne,st,sh,umar,wr,thi,kn,le sc,dth,pop E° dh,paf
5	E ne,st,psh,sc,dth E° ash,cf,dh,wr,athi, kn,ale,par,el	E pne,psh,sc,dth E° ane,lne,st,cf,dh,wr,athi, kn,le,par,el
5	E ane,wr,athi,kn,pne, psh,sc,dth E° st,lne,dh,le,par,el, pthi,pop	E ne,st,sh,umar,dh,wr,athi, kn,ale,sc,dth E° paf,el,pthi,pop,ple
5*	E° dh,wr,athi,kn,ale,pne, psh,par,el,sc,dth	E pne E° ane,lne,st,cf,wr,thi,kn,le, paf,psh,par,el,sc,dth,pop
5	E ne,st,sh,par,sc,dth E° aar,cf,dh,wr,athi, kn,ale,el	E ne,st,sh,cf,wr,paf,sc,dth E° umar,athi,kn,ale
4	V ear E ne E° psh,sc,dth	V ear E+ nne,lne E pne,psh,sc,dth E° aar,dh,wr,athi,kn
5	E pne,psh,sc,dth E° ane,lne,st,wr,dh, athi,kn,ale,par,el	E ne,kn,psh,sc,dth E° ash,umar,cf,wr,thi,le,par, el,pop
5	E psh,sc,dth E° ane,lne,athi,kn	E kn,psh,sc,dth,pop E° ne,st,thi,le

Av. 4.9+

Table XXV

Carbon Rayon #166 (22% Carbon) - Shoulder Patch Test

Conditions: H at CT 2400 (60 min.); 90°F, 65% R.H.
1-1/2 layer (CC-2 impregnated shorts)
Rayon #166 patch on left shoulder scapula and dorsal thorax of a Rayon #176 suit.

Date Started: 8/21/45

No. of Exposures Tolerated	Readings (Hours After Last Exposure)	
	24	48
2	E left psh,sc,dth E° right psh,sc,dth E° ne,st,athi,kn,ale	E left psh,sc,dth E° right psh,sc,dth E° ne,st,ash,aar,cf,thi,kn,le,pop
2	E left psh,sc,dth E° ane,lne,st	E left psh,sc,dth E° ane,lne,st
2	E left psh,sc,dth E° cf,pne	E left psh,sc,dth
2*	E° left psh,sc,dth E° kn,pne	E° left psh,sc,dth E° pne

Av. 2.0+

Table XXVI

Carbon Rayon #110

Conditions: HN-1 at CT 2000 (60 min.); 90°F, 65% R.H.
1-1/2 layer (Carbon Rayon #143 shorts, improvised carbon coated gloves and socks).

Date Started: 8/30/44

No. of Exposures Tolerated	Readings (Hours After Last Exposure) 24	48
5	E sc, no	E ar, sc
5*	E° scr, thi, kn	E no, scr E° kn
5	E sh, sc E° scr, dth, no	E sh, sc, dth E° no, scr
5	E pno E° sc	E pno, sh E° ano, lno, sc
5	E no	E no, sc E° sh
5	E sc E° no, ar	E sc, dth E° sh, scr

Av. 5.0+

Table XXVII

Summary of "Breaks" Per Day

Carbon Cloth	Date Started	No. of Men	CT of Exp.	No. of Men "Broken" on Day No. – 1	2	3	4	5	6	7	8	9	10	11	12	No. of Breaks	Av.Exp. Tolerated	Av.CT Tolerated
CarbonCoated S-38	7/3/45	7	1200					2	3	2						7	6.0	7200
Carbon Impregnated Casein	3/20/45	7	1200						1	3,1*	2					6	7.1+	8520+
Improved Casein	9/27/45	8	1200	1	6	1										8	2.0	2400
Methocel	7/6/45	7	1200			2	4,1*									6	3.7+	4440+
Carbon Rayon Costa (1 layer)	5/2/44	4	1200						4							4	6.0	7200
Costa (1-1/2 layer)	5/16/44	4	1200			1				1	1,1*					3	6.5+	7800+
110	5/16/44	4	1200						4							4	6.0	7200
110	11/7/44	2	1200			1		1								2	4.0	4800
148	10/31/44	4	1200									2			2*	2	10.5+	12600+
176	6/26/45	8	2400				4	3,1*								7	4.5+	10800+
191	6/26/45	7	2400			1	2	4								7	4.4	10560
193	6/26/45	8	2400				1	6,1*								7	4.9+	11760+
166	8/21/45	4	2400		3,1*											3	2.0+	4800
Test with HN-1 Carbon Rayon/110	8/30/44	6	2000					5,1*								5	5.0+	10000+

* Man withdrawn from test for reasons other than a "break".

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